Engine technical performance influence on car exhaust microparticles grading

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Abstract. Present work demonstrates the influence of the engine size, car production year and fuel type on suspended solid particles of the car exhaust. The investigated machine group (N = 21) showed no influence on the particle size distribution caused by engine displacement and type of fuel. It is shown that almost new cars (less than 400 km travelled) are the most frequent source of the particles with an average diameter of about 10 microns or less.
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Introduction

The contribution of vehicle emissions in the environmental pollution of the city is the most pronounced and ever-increasing [1; 2-5]. From an environmental perspective prognostically the most dangerous components of the exhaust gas are solid particles of soot, metal-containing particles, carbon monoxide, sulfur oxides and carbon nanomaterials [6-8]. This work continues a series of studies of the particulates in the vehicles exhaust gases [9; 10] and shows the application of the latest study method - laser granulometry.

Materials and methods

To conduct the experiments according to OH 025270 66 [11] Sectoral Normal Classification and Classification of Economic Commission for Europe, we have chosen the most significant in terms of ecology (emissions) and widely represented in the urban environment vehicle types (Table 1).

The cars, produced in 2013 year, were kindly provided by one of the auto dealers (Primorsky Krai) and the cars with high mileage (more than 100 000 km) belong to the authors and their colleagues. The vehicles were fueled with gasoline and diesel oil of one brand at the gas station of one and the same oil company. The aim of this work was to show the application of a new method for solving environmental problems, so the experiment was conducted under the cars that really move through the streets, rather than test bed engines. All measurements were carried out at idle. Also we do not have an extra goal to study chemical composition of the engine oil and fuel of the vehicles.

We chose the exhaust gas suspension as an object of investigation (methodology of measurements is described here [10]). Previously it was shown that the water neutralize the exhaust gases of internal combustion engines, efficiently absorbing solids [12; 13-15].

Table 1. Cars under experiment

	Code, production year	Engine capacity, L	Fuel type	Mileage, km
	Cars with capacity less than 2 l.			
1	KP 2013	1.0	gasoline	Less than 400
2	TCa 2001	1.3	gasoline	120 000
3	TCC 1996	1.3	gasoline	185000
4	TI 2003	1.5	gasoline	80000
5	TCo 1995	1.5	gasoline	280 000
6	TV 2006	1.6	gasoline	166 000
7	WP 2013	1.6	gasoline	Less than 400
8	NB 1993	1.7	diesel oil	276 000
	Cars with capacity from 2 to 3 l.			
9	WTi 2013	2.0	gasoline	Less than 400
10	WA 2013	2.0	diesel oil (turbo)	Less than 400
11	SE 2002	2.0	gasoline	137 000
12	SE 2002+	2.0	gasoline/gas	137 000
13	KMu 2013	2.0	diesel oil	Less than 400
14	KS 2013	2.4	gasoline	Less than 400
15	TS 2004	2.7	gasoline	125 000
	Cars with capacity more than 3 l.			
16	KM 2013	3.0	diesel oil (turbo)	менее 400
17	IB 1997	3.1	diesel oil	150 000
18	WT 2013	3.6	gasoline	61 000
19	TLCP 2010	4.0	gasoline	61 000
20	TLC 2004	4.7	gasoline	118 000
21	IQ 2005	5.6	gasoline	83000

Once the measuring has been completed, the container with distilled water, through which the exhaust gases have passed, was hermetically covered with a lid and sent to the laboratory. Using a sterile plastic syringe, the 60 ml volume sample was collected from the container after resuspension in the laboratory. Then the sample has been studied by the laser particle size analyzer Analysette 22 NanoTech (Fritsch Company). All measurements were made under the nanotec mode with carbon/water 20 ^{o}C settings with three replicates.

Results and discussion

Morphometric parameters of solids in the exhaust gas suspension were determined by the laser granulometry; they are presented in the Table 2.

Table 2. Morphometric parameters of solids in the exhaust gas suspension *

	Morphometric parameters				
Code, year	Arithmetic Mean Diameter, mkm	Mode, mkm	Median, mkm	Coefficiant of Variation, %	Spec. Surface Area, cm^2/cm^3
Cars with capacity less than 2 l.					
KP 2013	845.24	1003.38	930.31	25.11	217.87
TCa 2001	12.28	12.56	12.31	14.5	5018.31
TCC 1996	397.85	151.0	160.22	89.86	288.64
TI 2003	20.84	20.35	20.77	6.93	2892.76
TCo 1995	27.07	7.75	8.84	89.29	5023.83
TV 2006	863.73	1003.38	949.46	27.42	161.83
WP 2013	9.07	11.66	11.17	49.76	20568.69
NB 1993	44.36	25.43	26.31	85.19	4033.73
Cars with capacity from 2 to 3 l.					
WTi 2013	12.65	15.12	14.87	41.25	19195.78
WA 2013	334.7	495.62	440.22	70.29	1898.01
SE 2002	557.97	554.0	554.89	11.91	109.06
SE 2002+	25.79	14.04	14.19	139.8	3913.61
KMu 2013	21.07	21.92	22.0	22.73	3496.08
KS 2013	102.08	96.78	99.27	26.77	631.69
TS 2004	867.72	1003.38	966.06	33.38	360.66
Cars with capacity more than 3 l.					
KM 2013	13.44	13.04	13.38	9.59	4506.3
IB 1997	394.59	396.65	385.59	25.09	162.07
WT 2013	11.18	10.83	11.15	7.78	5397.07
TLCP 2010	964.91	1003.38	972.41	4.21	62.2
TLC 2004	49.85	42.76	43.88	61.0	1402.6
IQ 2005	867.76	1003.38	919.08	20.08	74.67

* - The morphometric parameters, considered to be dangerous for human health, are highlighted by the black color, while the parameters, considered as potential dangerous, are highlighted by grey marker.

As you can see in the table 2, the cars which are a source of particulate suspensions with the most dangerous indicator - the size of about 10 microns (highlighted in black in the table) have less than 400 km mileage in four cases out of five. Also, two maximum values of the specific surface area of particles (19195.78 and 20568.69 $см^2/см^3$) refer to vehicles with mileage less than 400 km.

Fig. 1 and 2 show typical histogram of particle sizes and their share in the exhausts of cars, produced in 2013 year, and running on gasoline.

Judging by the results, other cars, produced in 2013 year, without high mileages with a few exceptions (see Table. 2) are emitting relatively dangerous size fractions (from 10 to 50 microns). And only three cars without mileage throw the particles greater than 100 microns with the exhaust gases into the environment.

As our studies of experimental 21 cars have shown, fuel type does not have a serious impact on the granulometric pattern of particles (Fig. 3 and 4), although it is worth noting that, in general, gasoline engines produce the coarser fraction.

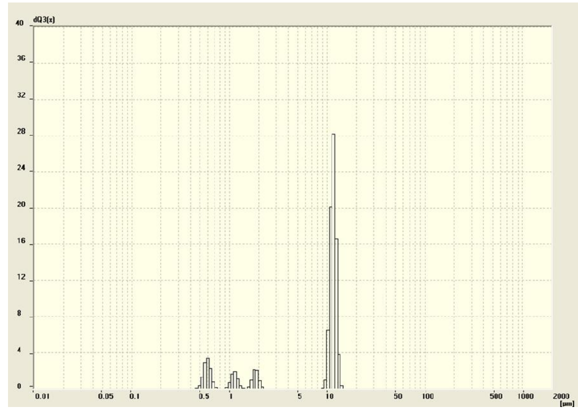

Fig. 1. Histogram of particle sizes and their share in typical exhaust sample of the car WP 2013 (gasoline, engine volume 1.6 liters). The ordinate shows a number of particles with a given size, the abscissa shows the particle size from 0.01 to 2000 microns.

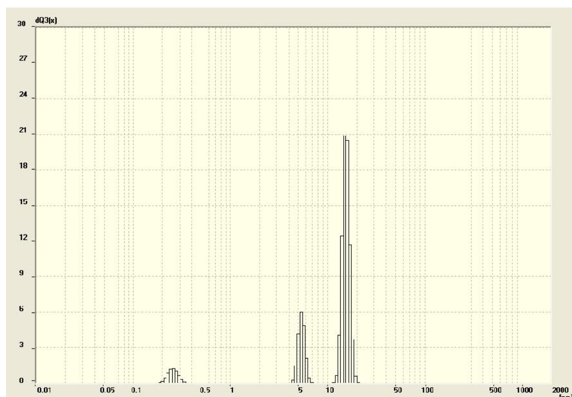

Fig. 2. Histogram of particle sizes and their share in typical exhaust sample of the car WTi 2013 (gasoline, engine volume 2.0 liters). The ordinate shows a number of particles with a given size, the abscissa shows the particle size from 0.01 to 2000 microns.

Also worth noting, that the cars are a source of well-differentiated and repeated particle size fractions. There are three main size classes of exhaust particulate matter:

1) 0.1-5 microns – refer to the highly dispersed carbon black particles and metal fine aggregates (first small peaks in Fig. 1 and 2);

2) 10-30 microns – the soot particles that presumably may relate to direct products of fuel combustion (the largest peak in Fig. 1 and 2, the middle peak in Fig. 3);

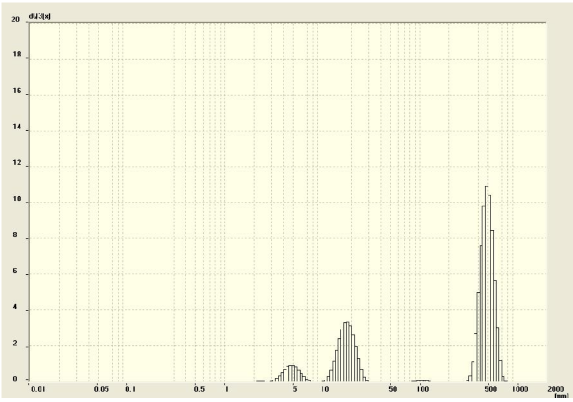

Fig.3. Histogram of particle sizes and their share in typical exhaust sample of the car WA 2013 (diesel oil (turbo), engine volume 2.0 liters). The ordinate shows a number of particles with a given size, the abscissa shows the particle size from 0.01 to 2000 microns

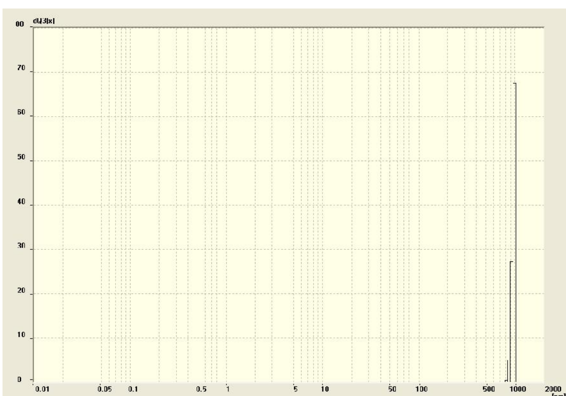

Fig. 4. Histogram of particle sizes and their share in typical exhaust sample of the car TLCP 2010 (gasoline, engine volume 4.0 liters). The ordinate shows a number of particles with a given size, the abscissa shows the particle size from 0.01 to 2000 microns

3) 400-1000 microns – the large soot particles; most likely, they are the products of unburned particulate accumulation (e.g., produced in the exhaust system when the engine starts), which can be detached from the surface upon reaching a certain size (the large peak in Fig. 3 and 4);

Conclusion

The analysis of internal combustion engine exhaust suspension made by the laser granulometry allows us to give an environmental assessment of particulate matter in terms of impact on human health. Thus, it is widely known that the greatest danger is caused by the exhaust particles having a diameter less than 10 micron [16; 17]. We found the particles with an average diameter about 10 microns in exhaust gas suspensions of 20% of the investigated vehicles (5 of 21). Besides, 4 more cars threw with the exhaust gas the particles with an average size of 20 microns, which can be considered as potentially dangerous to human health. It certainly allows placing the gasoline and diesel vehicles, both new and used, to the sources of atmospheric emissions of hazardous size fractions.

As an interesting observation it is also worth noting that the laser granulometry helped to reconfirm the fact [10] that not only cars with high mileage are a significant source of microdispersed particles and metals into the atmosphere due to their components wear. As it was shown, the new cars (without running) are also a source of no less and sometimes even bigger quantity of potentially hazardous microparticles.

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